RELATIVE DENSITY ESTIMATES

OF DESERT TORTOISE ON

EDWARDS AIR FORCE BASE, CALIFORNIA

AUGUST 1996

RELATIVE DENSITY ESTIMATES OF DESERT TORTOISE ON EDWARDS AIR FORCE BASE, CALIFORNIA

David M. Laabs, Biosearch Wildlife Surveys, PO Box 8043, Santa Cruz, CA, 95061
Mark L. Allaback, Biosearch Wildlife Surveys, PO Box 8043, Santa Cruz, CA, 95061
Brenda Ellis, Tetra Tech, Inc., 348 West Hospitality Lane, Suite 300, San Bernardino, CA. 92408
Don Mitchell, Tetra Tech, Inc., 348 West Hospitality Lane, Suite 300, San Bernardino, CA. 92408
Jody Sawasaki Tetra Tech, Inc., 348 West Hospitality Lane, Suite 300, San Bernardino, CA. 92408
Edward LaRue, Jr., Circle Mountain Biological Consultants, PO Box 3197, Wrightwood, CA 92397

Abstract: Surveys were conducted to estimate relative densities of desert tortoise (*Gopherus agassizii*) on Edwards Air Force Base (AFB), California. One hundred and five square mile sections were sampled using standardized Bureau of Land Management (BLM) relative density strip transects. Surveys were also conducted at BLM desert tortoise population trend plots with known tortoise densities in order to calibrate surveys at Edwards AFB. Relative densities of desert tortoise at Edwards AFB ranged from 0 to 25 individuals per square mile, with a mean of 10.5 per square mile (standard deviation = 4.3). Four live tortoise and 99 tortoise carcasses were located during the surveys. Analysis of human impacts indicate that much of the surface disturbance is historic and that current disturbances are localized. Other special-status species observed incidentally or detected by sign were northern harrier (*Circus cyaneus*), prairie falcon (*Falco mexicanus*), burrowing owl (*Athene cunicularia*), LeConte's thrasher (*Toxostoma lecontei*), loggerhead shrike (*Lanius ludovicianus*), desert kit fox (*Vulpes macrotis*) and American badger (*Taxidea taxus*).

The desert tortoise (*Gopherus agassizii*) is a large herbivorous reptile (Family: Testudinidae) whose range includes the Sonoran and Mojave deserts of southern California, southern Nevada, Arizona, extreme southwestern Utah, and Sonora and northern Sinaloa, Mexico. The species is listed by the United States Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG) as threatened.

The species is known to occur on Edwards Air Force Base (AFB) in Kern, Los Angeles, and San Bernardino counties, California. Surveys designed to estimate relative population densities of desert tortoise have been previously conducted at Edwards AFB (CSC 1991, Mitchell et al. 1992, Mitchell et al. 1993). The purpose of this study was to determine relative densities of desert tortoises in sections of the base which contain a significant amount of potential habitat for the species but had not been previously surveyed.

STUDY AREA

Edwards AFB covers approximately 1,217 square kilometers (470 square miles) or 121,700 hectares (300,700 acres) in Kern, San Bernardino, and Los Angeles counties. The base is bounded roughly by Highway 14 on the west, Highway 395 on the east, Highway 58 on the north, and Avenue E on the south.

A relatively small portion of the base is currently developed. Main base facilities are located along the western shore of Rogers Lake. The Phillips Laboratory facilities are situated east of Leuhman Ridge. In addition, there are several ancillary facilities throughout the site. A network of paved and dirt roads provides access to most areas.

Elevation ranges from 692 to 1,038 meters (2,270 to 3,404 feet). Rogers and Rosamond dry lakes represent the low elevation points. The base is split into east and west sides by Rogers Lake. Leuhman Ridge is the major geomorphologic feature on the east side. The Kramer Hills occupy the northeastern corner. Haystack Butte is the high point (1,030 meters) in the southeastern portion of the site. The Rosamond and Bissell hills are oriented roughly east-west in the northwestern part of the base. The southwestern portion of the site is dominated by dry lake and clay pan systems.

There are four major zonal habitats present on the study site. The most common is creosote bush scrub, which is dominated by creosote bush (*Larrea tridentata*) and burrobush (*Ambrosia dumosa*). Another common habitat on the site is Joshua tree woodland, which is dominated by creosote bush, burrobush, and Joshua tree (*Yucca brevifolia*). Two types of saltbush scrub have been delineated. Halophytic phase saltbush scrub occupies low-lying areas associated with dry lakes and playas and is dominated by several species of saltbush (*Atriplex* spp.) and inkweed (*Suaeda moquinii*). Arid phase saltbush scrub exists at higher elevations and supports allscale (*Atriplex polycarpa*), burrobush, and wolfberry (*Lycium andersonii*).

METHODS

Relative density strip transects were used to sample each section. Magellan System Corporation Nav 5000 Pro Global Positioning System units were used to navigate to the center of each section surveyed. Position fixes were recorded for the center as well as the corners of the transect triangles. A small degree of variation is normal in the system, therefore, positional data are reliable to $\pm$ 100 meters in the field. Using post-processing procedures, the positions recorded in the field were corrected to a greater degree of accuracy (up to $\pm$10 meters).

Five permanent BLM desert tortoise population trend plots were surveyed by each observer for calibration purposes. The Fremont Peak, Kramer Hills, Lucerne Valley, Johnson Valley, and Desert Tortoise Natural Area trend plots were surveyed between 09 and 12 August, and on 19 August, 1994. Each observer performed six transects at each of the five study locations. Population density estimates were obtained from the BLM (Berry, personal communication), and are based on a Stratified Lincoln Index of mark-recapture data collected in 1993 and 1994. All field surveys were conducted by Mark Allaback, David Laabs, and Edward LaRue between 11 July, and 19 August, 1994.

The sections sampled in 1994 represent the sections not surveyed by Tetra Tech in the 1992 and 1993 studies, excluding sections within dry lakes, operational areas, housing areas, and areas previously surveyed. Three transects were surveyed in each of 105 sections for a total of 315 transects. The center of each section was used as the starting point for transects. Transect orientation was chosen to avoid buildings and areas which could pose a health or safety threat to surveyors. Transects were oriented to sample only potential habitat in sections that were largely occupied by dry lakes or other unsuitable habitat (Figure 1).

Each transect consisted of an equilateral triangle, with each leg 0.8 kilometer (0.5 mile) long for a total of 2.4 kilometers (1.5 miles). Transects were walked slowly in a counterclockwise direction. All tortoise sign within 10 meters (33 feet) of the transect centerline was recorded. Data were recorded on preformatted data forms developed by the BLM and Gilbert O. Goodlet. In addition to a general site description and locational data, several types of tortoise sign were recorded including burrows, scat, carcasses, and live tortoises (Berry and Nicholson 1994). Sign that indicates the presence of a single tortoise, such as multiple scats in a burrow or scats of similar size and age in close proximity, were counted as a single "corrected sign," and tallied.

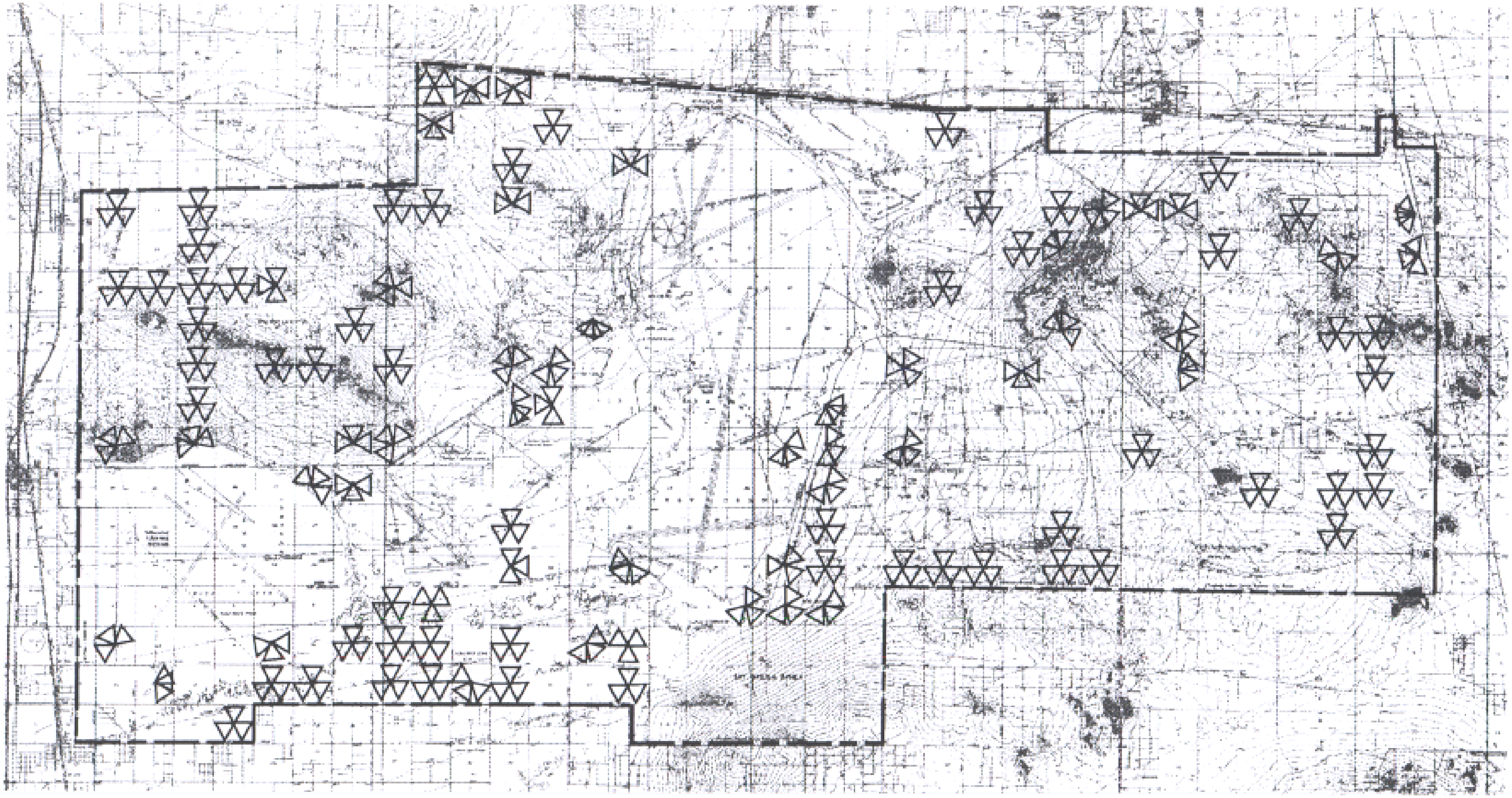
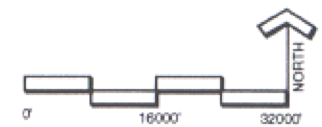


FIGURE 1
LOCATION OF 1994
DESERT TORTOISE TRANSECTS
EDWARDS AFB



E055_007/maedrw 8/21/95

Relative density estimates were calculated using equations derived by relating counts of desert tortoise scats and cover sites in the study area to sign counts at BLM desert tortoise population trend plots where densities have been previously measured. Transect orientation was offset slightly for each observer so that all transects were unique. Mean sign counts for each trend plot were plotted against the tortoise density for those plots. A simple regression line was then fitted to these points and the 0,0 point for each observer.

Human-related disturbances were also recorded on the data sheets (CSC 1991). Counts of each disturbance type were totaled for each section. The percentage of sections in which each disturbance type occurred was calculated, as was the mean count of each disturbance type over all sections.

RESULTS

Calibration. Regression analysis of average total corrected sign observed against population density at BLM trend plots was performed for each observer. The point 0,0 was used in regression analysis, but the line was not forced through this point. The coefficient of determination was low for all observers (0.29, 0.28 and 0.22). When the results from the Kramer Hills plot were removed (see discussion), r2 for all observers was high (0.76, 0.75 and 0.73). Regression lines for all observers crossed the y-axis near 7 (Figure 2).

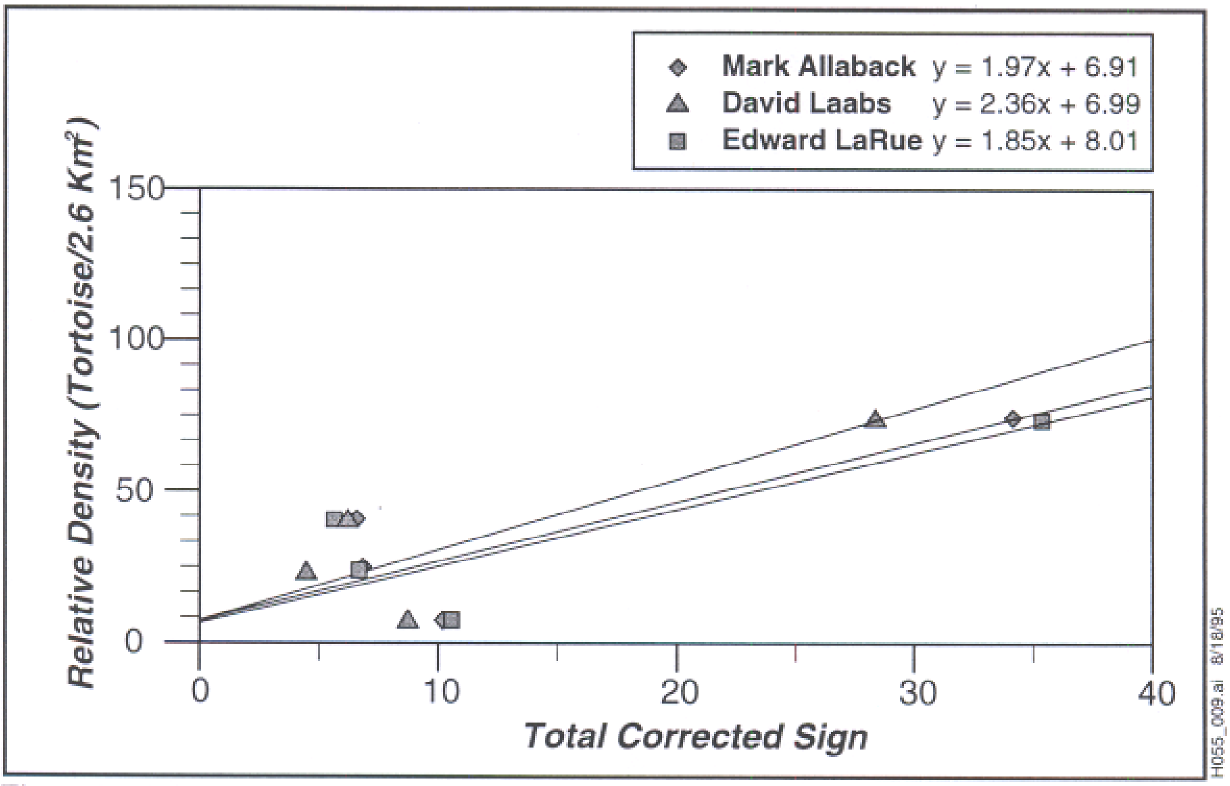


Figure 2 Linear regression of results from BLM Trend Plots, August 1994.

Estimated Relative Densities. Estimated densities of desert tortoise were calculated using equations of regression lines for each observer utilizing data collected at the BLM study plots. Table 1 presents the results by transect and density estimates from each section, derived by averaging the estimated densities for all observers in that section.

Estimated desert tortoise densities ranged from 7 to 25 tortoises per square mile at Edwards AFB. The mean density of all sections surveyed was 10.5 tortoises per square mile with a standard deviation of 4.3. Figure 3 presents the density distribution across the study site. Figure 4 presents density distribution across the base including results from previous studies (CSC 1991, Mitchell et al. 1992, Mitchell et al. 1993) according to zonal habitats on the base.

Desert tortoise densities were substantially higher on the east side of the base compared to the west side. The mean density for 46 sections surveyed on the east side was 12.75, while the mean density of 59 sections on the west side was 8.7. Tortoise sign was not detected in 31 of 59 (52.5%) sections on the west side of Edwards AFB, while only 8 of 46 (17.4%) sections lacked tortoise sign on the east side.

Desert tortoise abundance is not distributed uniformly across the base. On the east side of the base, above average densities were found in the vicinity of Jack Rabbit Hill, the Kramer Hills and the north side of Leuhman Ridge. On the west side of Edwards AFB, above average densities were recorded only from the Rosamond and Bissell hills.

Tortoise abundance was consistently low in the southwest portion of the base. Much of this area is covered by playa and clay pan systems. Tortoise sign was detected in only a single section south of the north edge of Rosamond Dry Lake and west of Complex One Charlie.

Observations of live tortoises and carcasses. Although methodology focused primarily on evidence of tortoise activity, four observations of live tortoises were made over the course of the study. Table 2 presents the locations of these individuals. All tortoises observed appeared healthy.

Ninety-nine desert tortoise carcasses were observed during transects. The use of a key prepared by Berry & Woodman (1984) for determining time since death was restricted somewhat by time and handling restrictions, and certain distinctions were not possible. Therefore, data are divided into four categories: less than 1 year; 1 to 4 years; greater than 4 years; and unknown. Table 3 presents these results.

Twenty-eight of the 99 tortoise carcasses (28%) were estimated to be less than or equal to 4 years old. A concentration of 12 carcasses less than 4 years old occurred on the west side of the base, near the north entrance to Edwards AFB. Tortoise carcasses were encountered more frequently on the east side of the base than on the west. Sixty-two carcasses were observed in the 46 sections surveyed on the east side (1.35 carcasses per section), while 37 carcasses were detected in the 59 sections surveyed on the west side (0.63 carcasses per section).

Table 1

1994 Desert Tortoise Transect Results

Transect Number	Location			Date Surveyed	Surveyor*	Transect Orientation	Total Sign	Total Corrected Sign	Estimated Relative Density	Mean Density for Section
	T	R	Sec							
1	11N	10W	31	19-Jul	MA	S	1	1	9	9
					DL	NE	3	1	9	
					EL	NW	1	1	10	
2	11N	10W	32	19-Jul	MA	E	1	1	9	8
					DL	W	0	0	7	
					EL	S	0	0	8	
3	11N	10W	33	19-Jul	MA	W	3	2	11	11
					DL	S	1	1	9	
					EL	E	2	2	12	
4	10N	10W	35	16-Aug	MA	SW	0	0	7	9
					DL	S	1	1	9	
					EL	SE	1	1	10	
5	10N	10W	6	22-Jul	MA	E	0	0	7	7
					DL	W	0	0	7	
					EL	S	0	0	8	
6	10N	10W	3	7-Aug	MA	SE	1	1	9	9
					DL	N	1	1	9	
					EL	SW	0	0	8	
7	10N	10W	12	16-Aug	MA	E	0	0	7	10
					DL	N	2	2	12	
					EL	W	2	2	12	
9	10N	8W	5	13-Aug	MA	N	7	6	19	14
					DL	SW	3	3	14	
					EL	SE	0	0	8	
10	10N	10W	9	22-Jul	MA	N	3	3	13	9
					DL	SW	0	0	7	
					EL	SE	0	0	8	
11	10N	7W	9	5-Aug	MA	N	7	5	17	23
					DL	SW	9	7	24	
					EL	SE	12	11	28	
12	10N	12W	14	16-Jul	MA	SE	0	0	7	7
					DL	N	0	0	7	
					EL	SW	0	0	8	
13	10N	11W	18	16-Jul	MA	SW	0	0	7	9
					DL	SE	0	0	7	
					EL	N	2	2	12	
14	10N	11W	13	12-Jul	MA	SW	4	3	13	9
					DL	SE	0	0	7	
					EL	N	0	0	8	
15	10N	10W	18	11-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
16	10N	10W	16	22-Jul	MA	W	0	0	7	9
					DL	E	1	1	9	
					EL	N	1	1	10	
17	10N	8W	16	13-Aug	MA	SW	9	5	17	12
					DL	SE	0	0	7	
					EL	N	3	3	14	
18	10N	8W	14	17-Aug	MA	SW	8	5	17	15
					DL	SE	8	6	21	
					EL	N	0	0	8	
19	10N	8W	13	8-Aug	MA	NE	0	0	7	14
					DL	W	25	7	24	
					EL	SE	7	2	12	

Table 1, Page 2 of 6

Transect Number	Location T	R	Sec	Date Surveyed	Surveyor*	Transect Orientation	Total Sign	Total Corrected Sign	Estimated Relative Density	Mean Density for Section
20	10N	7W	18	8-Aug	MA	W	0	0	7	8
					DL	E	1	1	9	
					EL	N	0	0	8	
21	10N	7W	17	8-Aug	MA	N	10	6	19	18
					DL	W	2	2	12	
					EL	E	8	8	23	
22	10N	7W	14	5-Aug	MA	SW	8	5	17	18
					DL	SE	3	3	14	
					EL	N	8	8	23	
23	10	6W	17	2-Aug	MA	NW	0	0	7	12
					DL	SW	3	3	14	
					EL	SW	6	3	14	
24	10N	11W	19	19-Jul	MA	N	1	1	9	8
					DL	SE	0	0	7	
					EL	SW	0	0	8	
25	10N	8W	22	17-Aug	MA	SE	0	0	7	7
					DL	N	0	0	7	
					EL	SW	0	0	8	
26	10N	8W	23	17-Aug	MA	N	31	8	23	13
					DL	NW	1	1	9	
					EL	W	0	0	8	
27	10N	7W	21	5-Aug	MA	SE	0	0	7	13
					DL	N	2	2	12	
					EL	SW	13	7	21	
28	10N	7W	24	2-Aug	MA	SW	7	5	17	19
					DL	SE	6	4	16	
					EL	NW	10	9	25	
29	10N	6W	20	2-Aug	MA	N	3	3	13	13
					DL	W	4	3	14	
					EL	S	2	2	12	
30	10N	12W	26	15-Jul	MA	SE	1	1	9	8
					DL	N	0	0	7	
					EL	SW	0	0	8	
31	10N	12W	25	15-Jul	MA	N	0	0	7	8
					DL	SW	0	0	7	
					EL	SE	2	1	10	
32	10N	11W	30	18-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
33	10N	11W	29	18-Aug	MA	SE	1	1	9	8
					DL	N	0	0	7	
					EL	SW	0	0	8	
34	10N	11W	28	18-Aug	MA	W	5	4	15	17
					DL	S	1	1	9	
					EL	N	11	10	27	
35	10N	11W	25	18-Aug	MA	SW	14	10	27	15
					DL	NW	2	2	12	
					EL	E	0	0	8	
36	10N	8W	29	13-Aug	MA	SE	0	0	7	7
					DL	N	0	0	7	
					EL	SW	0	0	8	
40	10N	11W	31	18-Jul	MA	SW	0	0	7	13
					DL	SE	14	6	21	
					EL	N	1	1	10	
41	10N	11W	35	12-Jul	MA	SE	0	0	7	8
					DL	N	1	1	9	
					EL	SW	0	0	8	

Table 1, Page 3 of 6

Transect Number	Location T	Location R	Location Sec	Date Surveyed	Surveyor*	Transect Orientation	Total Sign	Total Corrected Sign	Estimated Relative Density	Mean Density for Section
42	10N	8W	35	15-Aug	MA	NW	0	0	7	7
					DL	SE	0	0	7	
					EL	NE	0	0	8	
43	10N	7W	32	8-Aug	MA	NE	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
44	10N	7W	36	17-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
45	10N	6W	31	17-Jul	MA	SW	12	9	25	25
					DL	SE	13	8	26	
					EL	N	11	9	25	
46	9N	11W	6	4-Aug	MA	SE	1	1	9	13
					DL	N	8	5	19	
					EL	SW	1	1	10	
47	9N	11W	4	19-Jul	MA	SW	1	1	9	14
					DL	SE	4	4	16	
					EL	N	5	5	17	
48	9N	11W	3	12-Jul	MA	SW	6	3	13	11
					DL	SE	5	2	12	
					EL	N	0	0	8	
49	9N	11W	1	12-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
50	9N	10W	3	1-Aug	MA	SW	0	0	7	7
					DL	SE	0	0	7	
					EL	NE	0	0	8	
51	9N	8W	6	18-Jul	MA	SE	1	1	9	8
					DL	W	0	0	7	
					EL	SE	0	0	8	
52	9N	8W	3	16-Aug	MA	E	0	0	7	8
					DL	W	1	1	9	
					EL	S	0	0	8	
53	9N	10W	4	14-Aug	MA	NW	0	0	7	13
					DL	W	2	2	12	
					EL	SW	10	7	21	
54	9N	7W	5	8-Aug	MA	SE	1	1	9	8
					DL	E	0	0	7	
					EL	NE	0	0	8	
55	9N	6W	6	17-Jul	MA	SE	15	9	25	13
					DL	N	0	0	7	
					EL	SW	0	0	8	
56	9N	11W	7	4-Aug	MA	SW	5	4	15	16
					DL	SE	4	4	16	
					EL	N	4	4	15	
57	9N	10W	9	1-Aug	MA	NE	5	3	13	12
					DL	SE	1	1	9	
					EL	SE	3	3	14	
58	9N	10W	10	1-Aug	MA	S	0	0	7	7
					DL	N	0	0	7	
					EL	W	0	0	8	
59	9N	9W	11	16-Aug	MA	S	0	0	7	7
					DL	SE	0	0	7	
					EL	E	0	0	8	
62	9N	12W	14	17-Aug	MA	SW	0	0	7	9
					DL	NE	2	2	12	
					EL	NW	0	0	8	

Table 1, Page 4 of 6

Transect Number	Location			Date Surveyed	Surveyor*	Transect Orientation	Total Sign	Total Corrected Sign	Estimated Relative Density	Mean Density for Section
	T	R	Sec							
					MA	NE	2	2	11	
63	9N	11W	18	17-Aug	DL	N	0	0	7	9
					EL	W	0	0	8	
					MA	E	0	0	7	
64	9N	11W	14	14-Aug	DL	N	0	0	7	8
					EL	W	1	1	10	
					MA	SW	0	0	7	
65	9N	11W	13	14-Aug	DL	NE	0	0	7	7
					EL	NW	0	0	8	
					MA	SE	0	0	7	
66	9N	9W	15	15-Aug	DL	NE	0	0	7	7
					EL	SW	0	0	8	
					MA	S	0	0	7	
67	9N	9W	14	3-Aug	DL	NE	0	0	7	9
					EL	SE	3	3	14	
					MA	SW	0	0	7	
68	9N	8W	18	18-Jul	DL	SE	1	1	9	8
					EL	NE	0	0	8	
					MA	SE	0	0	7	
69	9N	7W	18	14-Jul	DL	N	1	1	9	11
					EL	SW	14	5	17	
					MA	SE	0	0	7	
70	9N	6W	18	21-Jul	DL	N	2	2	12	9
					EL	SW	0	0	8	
					MA	SE	0	0	7	
71	9N	11W	22	20-Jul	DL	NE	0	0	7	7
					EL	NW	0	0	8	
					MA	E	0	0	7	
72	9N	11W	23	20-Jul	DL	W	0	0	7	7
					EL	S	0	0	8	
					MA	SE	0	0	7	
73	9N	9W	23	4-Aug	DL	SW	0	0	7	7
					EL	NE	0	0	8	
					MA	SW	8	6	19	
75	9N	7W	22	21-Jul	DL	SE	6	5	19	16
					EL	N	3	2	12	
					MA	SE	1	1	9	
76	9N	7W	24	16-Jul	DL	N	2	2	12	12
					EL	SW	5	4	15	
					MA	SW	0	0	7	
77	9N	6W	19	16-Jul	DL	SE	1	1	9	8
					EL	N	0	0	8	
					MA	N	0	0	7	
78	9N	10W	28	18-Aug	DL	SW	0	0	7	7
					EL	SE	0	0	8	
					MA	SE	0	0	7	
80	9N	9W	26	4-Aug	DL	N	3	3	14	10
					EL	SW	0	0	8	
					MA	SW	26	15	36	
81	9N	8W	26	14-Jul	DL	SE	1	1	9	19
					EL	N	3	2	12	
					MA	N	3	3	13	
82	9N	7W	25	16-Jul	DL	SW	15	8	26	18
					EL	SE	5	4	15	
					MA	S	0	0	7	
83	9N	10W	33	18-Aug	DL	E	0	0	7	7
					EL	N	0	0	8	

Table 1, Page 5 of 6

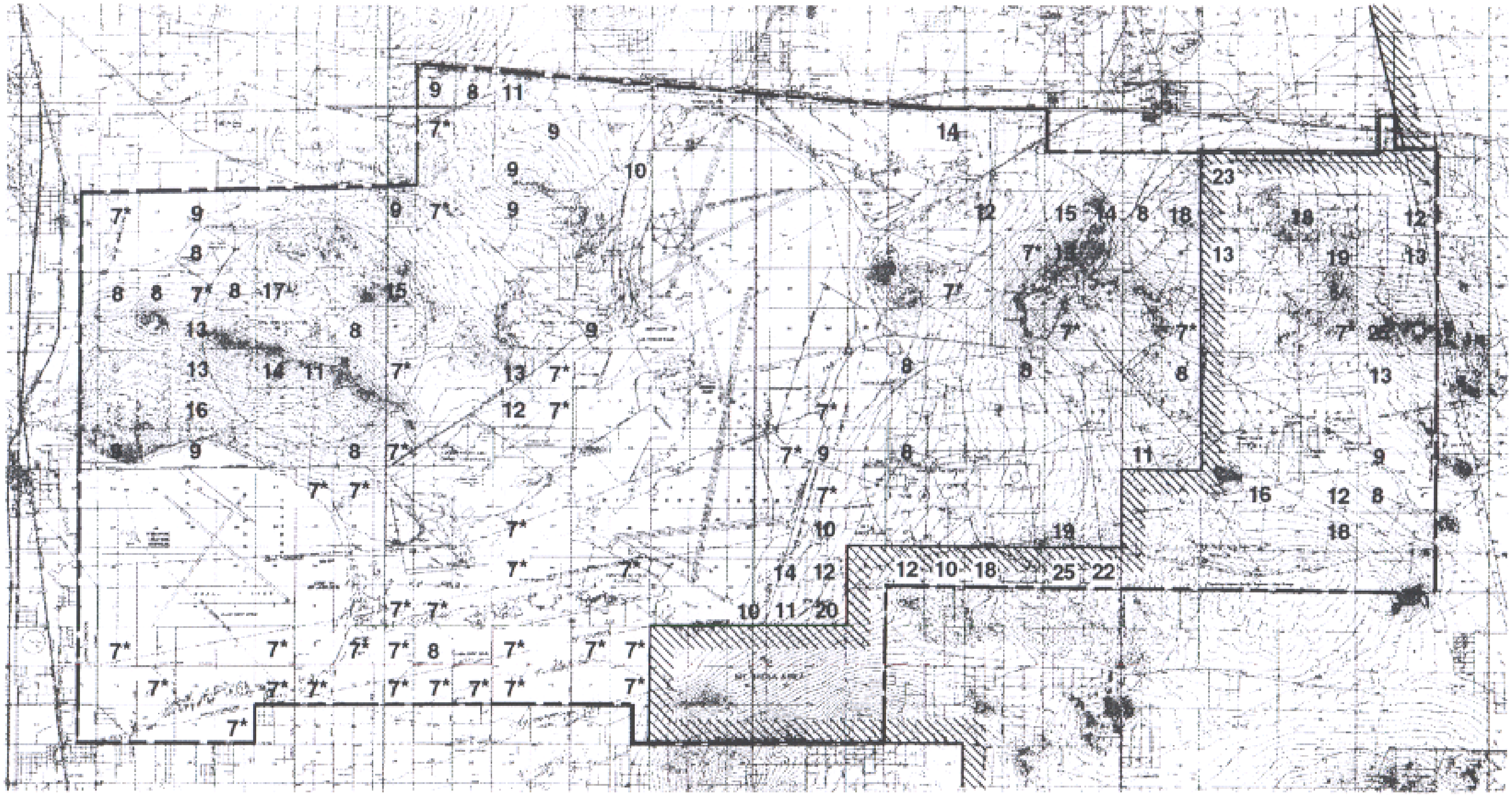
Transect Number	Location T	R	Sec	Date Surveyed	Surveyor*	Transect Orientation	Total Sign	Total Corrected Sign	Estimated Relative Density	Mean Density for Section
84	9N	10W	36	13-Aug	MA	NW	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
85	9N	9W	34	3-Aug	MA	W	0	0	7	14
					DL	SE	17	8	26	
					EL	NE	0	0	8	
86	9N	9W	35	20-Jul	MA	SW	5	4	15	12
					DL	SE	3	2	12	
					EL	N	0	0	8	
87	9N	8W	31	15-Jul	MA	N	2	2	11	12
					DL	SW	0	0	7	
					EL	SE	10	6	19	
88	9N	8W	32	15-Jul	MA	SW	1	1	9	10
					DL	SE	1	1	9	
					EL	N	2	2	12	
89	9N	8W	33	20-Jul	MA	N	16	9	25	18
					DL	SW	6	4	16	
					EL	SE	2	2	12	
90	9N	8W	35	21-Jul	MA	N	18	7	21	25
					DL	SW	12	10	31	
					EL	SE	16	9	25	
91	9N	8W	36	20-Jul	MA	SE	37	16	38	22
					DL	N	1	1	9	
					EL	SW	11	6	19	
92	8N	11W	1	15-Aug	MA	SW	0	0	7	7
					DL	SE	0	0	7	
					EL	N	0	0	8	
93	8N	10W	6	14-Aug	MA	NE	0	0	7	7
					DL	NW	0	0	7	
					EL	S	0	0	8	
94	8N	9W	4	15-Aug	MA	NE	1	1	9	10
					DL	SW	0	0	7	
					EL	SE	3	3	14	
95	8N	9W	3	3-Aug	MA	NE	4	4	15	11
					DL	SW	1	1	9	
					EL	SE	0	0	8	
96	8N	9W	2	4-Aug	MA	SW	13	6	19	20
					DL	SE	14	6	21	
					EL	NE	7	6	19	
97	8N	12W	11	3-Aug	MA	NE	0	0	7	7
					DL	SW	0	0	7	
					EL	NW	0	0	8	
98	8N	11W	9	2-Aug	MA	E	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
99	8N	11W	11	2-Aug	MA	SE	0	0	7	7
					DL	N	0	0	7	
					EL	SW	0	0	8	
100	8N	11W	12	15-Aug	MA	NE	0	0	7	7
					DL	NW	0	0	7	
					EL	SW	0	0	8	
101	8N	10W	7	14-Aug	MA	N	1	1	9	8
					DL	SW	0	0	7	
					EL	SE	0	0	8	
103	8N	10W	9	22-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	

Table 1, Page 6 of 6

Transect Number	Location			Date Surveyed	Surveyor*	Transect Orientation	Total Sign	Total Corrected Sign	Estimated Relative Density	Mean Density for Section
	T	R	Sec							
104	8N	10W	11	13-Aug	MA	SW	0	0	7	7
					DL	SE	0	0	7	
					EL	NE	0	0	8	
105	8N	10W	12	14-Jul	MA	NW	0	0	7	7
					DL	S	0	0	7	
					EL	NE	0	0	8	
106	8N	12W	13	17-Aug	MA	NE	0	0	7	7
					DL	SE	0	0	7	
					EL	E	0	0	8	
107	8N	11W	16	21-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
108	8N	11W	15	17-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
109	8N	11W	13	14-Jul	MA	SW	0	0	7	7
					DL	SE	0	0	7	
					EL	N	0	0	8	
110	8N	10W	18	14-Jul	MA	N	0	0	7	7
					DL	SW	0	0	7	
					EL	SE	0	0	8	
111	8N	10W	17	16-Aug	MA	SE	0	0	7	7
					DL	NW	0	0	7	
					EL	SW	0	0	8	
112	8N	10W	16	22-Jul	MA	SE	0	0	7	7
					DL	N	0	0	7	
					EL	SW	0	0	8	
113	8N	10W	13	16-Jul	MA	SE	0	0	7	7
					DL	N	0	0	7	
					EL	SW	0	0	8	
114	8N	11W	20	3-Aug	MA	N	0	0	7	7
					DL	E	0	0	7	
					EL	SW	0	0	8	

Note: Surveyors
MA = Mark Allaback
DL = David Laabs
EL = Ed LaRue

When no sign was detected, the mean for the section is recorded as 7 tortoise per section.



LEGEND

Designated critical habitat

Numbers = INDIVIDUALS/2.6 Km^2

* = Sections with zero sign detected

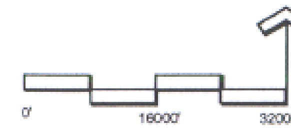
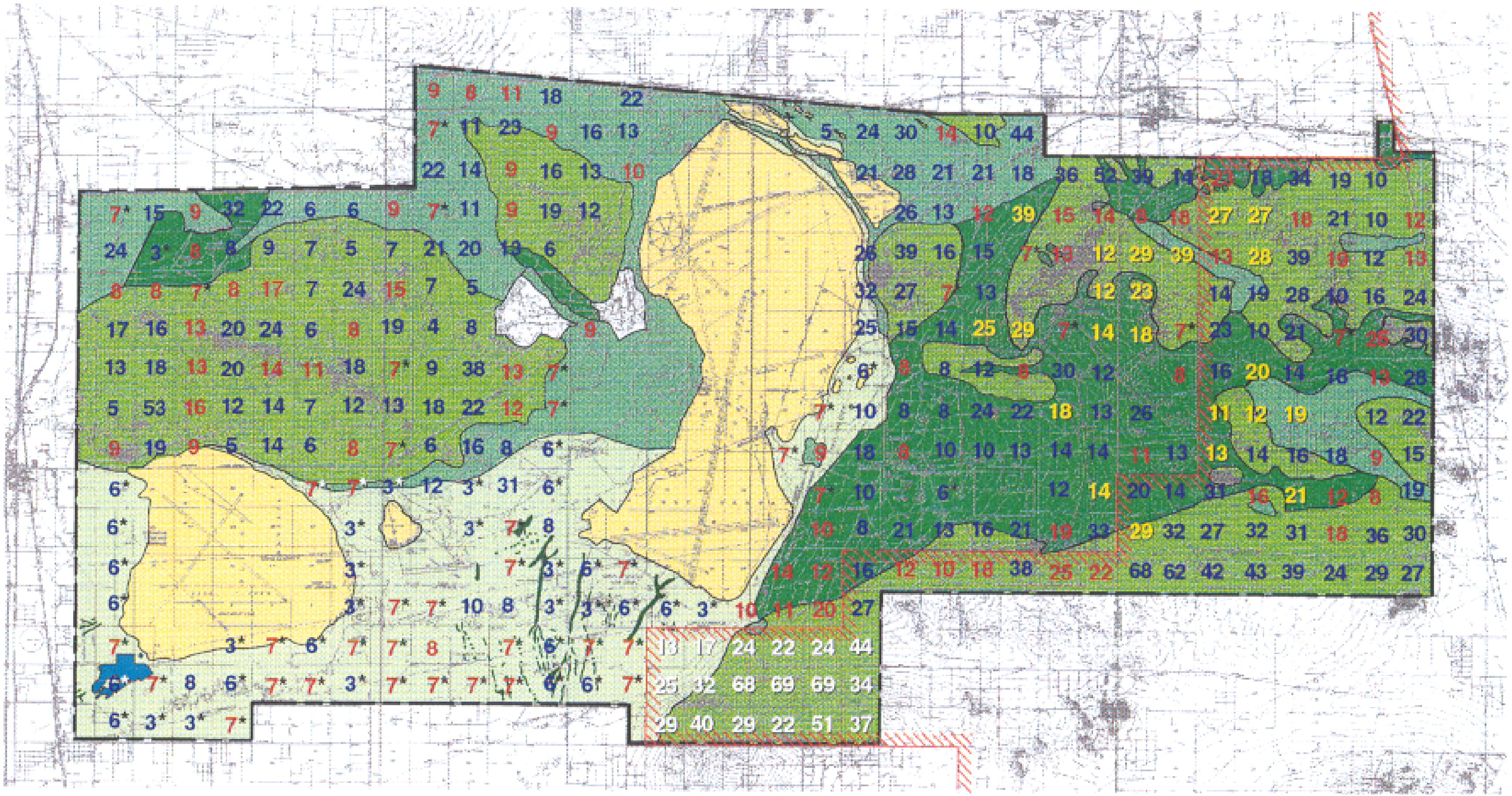


FIGURE 3
DESERT TORTOISE RELATIVE
DENSITIES IN 1994 SURVEYED
SECTIONS ON EDWARDS AFB

E065_008.macdw 8/21/96



LEGEND

ZONAL HABITATS:

- Halophytic Phase Saltbush Scrub
- Arid Phase Saltbush Scrub
- Creosote Bush Scrub
- Joshua Tree Woodland
- Playa Lake

AZONAL HABITAT:

- Mesquite Woodland

OTHER

- Urban Landscape (Within Base Boundaries)
- Ponds
- Designated critical habitat

Numbers = INDIVIDUALS/2.6 Km²

XX = From CSC, 1991
XX = From Mitchell, et al 1992
XX = From Mitchell, et al 1993
XX = Current study
* = Sections with zero sign detected

Source: Modified from D. Charlton 1991

FIGURE 4
DESERT TORTOISE RELATIVE DENSITIES (INDIVIDUALS/2.6 Km²) WITH MAJOR HABITAT FEATURES

NORTH

0' 16000' 32000'

E055_005.macdrw 8/27/96

Table 2

Locations of Observations of Live Tortoises During Relative Density Transects

ID#	T	R	Sec	Date	Sex	Age	Notes	Observer
22	10N	7W	14	8/5/94	Male	Adult	Resting	EL
82	9N	7W	25	7/16/94	Unknown	Adult	Within burrow	DL
85	9N	9W	34	8/3/94	Male	Adult	Within burrow	DL
96	8N	9W	2	8/4/94	Unknown	Adult	Within burrow	DL

Table 3

Time Since Death of Desert Tortoise Carcasses

	<1 yr	1-4 yrs	>4 yrs	Total
Male	2	10	7	19
Female	1	10	7	18
Unknown	0	5	57	62
Total	3	25	71	99

Human-related Disturbances. Table 4 presents the occurrence of human-related disturbance types by section. Disturbances of different types were not tallied together because the overall effect of disturbance types on tortoises are not considered to be equally weighted.

At least one disturbance type was recorded in every section. As few as 3 and as many as 13 different types of disturbance were recorded on a single section. The mean number of disturbance types per section was 7.84 (standard deviation = 2.06).

Paved roads occurred in 15 sections (14%), while dirt roads were present on 86 (82%) of all sections sampled. In addition, non-maintained roads and tracks resulting from off-road vehicle use were very common across the base. Non-maintained dirt roads occurred on 77 sections (73%), while tracks were observed on 93 sections (89%).

Evidence of livestock use (sheep, cattle and burro) was widespread. Cattle grazing was detected on 65 sections (62%), however, all sign of cattle was very old (>40 years). Evidence of sheep grazing was recorded on 56 sections (53%). Some of this sign was of recent origin, notably in the northwestern part of the base. In some areas, the effects of grazing appeared to have had a negative effect on both annual and perennial plant growth. Sign of feral burros was observed on 34 sections (32%). Most of the burro sign was old although occasionally fairly recent sign(5 to 10 years old) was encountered in Joshua tree woodland on the east side of the base. The highest concentrations of burro sign were along the southeastern side of Rogers Dry Lake.

Table 4

Human Disturbances on Desert Tortoise Transects

ID#	Location			Paved Roads	Dirt Roads	Dirt Trails	Dirt Tracks	Garbage	Shells	Shooting Targets	Test Pits	Camp Sites	Sheep	Cattle	Burros	Dogs	Fences	Utility Lines	Habitat Denuded	Partially Denuded	Old Buildings	Bomb Craters	Rail-Road	Dump Site
	T	R	Sec																					
1	11N	10W	31				5	28	3	1			3800					2	2					
2	11N	10W	23		18	5	4	34	16	4	1		1420					4	1				4	10
3	11N	10W	33		5			35	1				1085	1				2					2	13
4	10N	10W	35		2	4		31	2				145											2
5	10N	10W	6		6		11	13	3				4420		3			1					2	
6	10N	10W	3				17	1					154											
7	10N	10W	12	4	14	11	14	155			1							11	1	1			4	44
9	10N	8W	5		4		9	24	1				450	5				4						1
10	10N	10W	9				13	12					6	1										
11	10N	7W	9		2	2	3	6	3				240	6										
12	10N	12W	14		4	1	9	46	6				389			1								
13	10N	11W	18		4		8	9	18	1			3491	2										
14	10N	11W	13		16	3	11	40	17	13			463	1				6						
15	10N	10W	18		21	8	18	22	1	2			88					7		2				
16	10N	10W	16		2	2	17	42	1															
17	10N	8W	16	4	9	3	14	97	1				15		1			3						
18	10N	8W	14		2	4	1	12	22				325											
19	10N	8W	13		5	11	8	21	62				589	7	27		7	2					2	
20	10N	7W	18		12	4	5	53	288					7	43		1	4						
21	10N	7W	17			3	2	51	90		1		1322	1										
22	10N	7W	14		4	4	1	31	21		1		16											
23	10N	6W	17		6		1	22	20				2	2										1
24	10N	11W	19		8	5	4	26	19				58	3						5				2
25	10N	8W	22		5	2		26	18				50	53				2						
26	10N	8W	23			1	2	33	22					1										
27	10N	7W	21		5	3	2	222	1959						3							3		2
28	10N	7W	24		2	10	12	94	67		2			1										
29	10N	6W	20		4	2	4	8	10				1						1					
30	10N	12W	26		6	7	10	139	139	42		1	135	7	1									4
31	10N	12W	25		2		21	30	32	21			120	5										
32	10N	11W	30		2	5	26	52	70	4			6	9					2	1				7
33	10N	11W	29		2	7	8	27	22	1			89							2				1
34	10N	11W	28		6	2	14	34	38				280	1										1
35	10N	11W	25		6	16	105	15	6				173											
36	10N	8W	29		6			43	4				27	28	1									
40	10N	11W	31			9	65	14	30				83	2										
41	10N	11W	35		5	2	22	17	3				23	4					1					
42	10N	8W	35	3	5	7	2	62	9								2	3						1
43	10N	7W	32					13	49				3	4	1									
44	10N	7W	36			1		19	3				425	3										
45	10N	6W	31		2	4		9	4				503	14				4						
46	9N	11W	6		4	5	70	3					1	2										
47	9N	11W	4		4	2	74	6																
48	9N	11W	3		10	3	43	14	88	3			1	2										
49	9N	11W	1		10	4	99	13	5	1			1											
50	9N	10W	3	1	8	11	50	344	3									3						2
51	9N	8W	6		8	7	4	56	3				6	4	749			3			1			2
52	9N	8W	3		13	6	15	130	1					5	26			6	1					4
53	9N	10W	4	8	5	10	254	87	1		1		1					2						1
54	9N	7W	5		4	2		7	281				3	5	15			4						
55	9N	6W	6		4	4	5	13	4				105	12	1									
56	9N	11W	7		4	10	133	7	20					2										
57	9N	10W	9		12	9	62	44	8															1
58	9N	10W	10		8	9	37	80	8								1	4	1			1		5
59	9N	9W	11	6				92						8	1084		6							

ID#	Location T	Location R	Location Sec	Paved Roads	Dirt Roads	Dirt Trails	Dirt Tracks	Garbage	Shells	Shooting Targets	Test Pits	Camp Sites	Sheep	Cattle	Burros	Dogs	Fences	Utility Lines	Habitat Denuded	Partially Denuded	Old Buildings	Bomb Craters	Rail-Road	Dump Site
62	9N	12W	14	2	13	33	395	127	169	6	1	4	3					3		1				11
63	9N	11W	18	4	13	26	255	311	38	13				16			9	1	1		1			11
64	9N	11W	14			5	88	19	2	2	1													
65	9N	11W	13			2	85	12	3															1
66	9N	9W	15		4		2	19	527					3	1									1
67	9N	9W	14		10	5	4	76	4					19	853		7	5			1			6
68	9N	8W	18	2	14	5	18	168	124				2	3	51					1		4		2
69	9N	7W	18		5	1	2	10	3				2	8	2			4						
70	9N	6W	18		9	8	10	20	252		1			21	77									
71	9N	11W	22		3	4	10	33	7	1				15	8									2
72	9N	11W	23			2	6	8	5				3	13	4									
73	9N	9W	23		2	6	2	43	63					9	406							1		1
75	9N	7W	22		7	2	8	23	90				2	6	2									1
76	9N	7W	24		4	4	12	10	27					11				4						
77	9N	6W	19				3	6	5					9				2						
78	9N	10W	28		2	9	13	39	1				3	3	1		9							3
80	9N	9W	26		4	4	1	90	15				1	5	92		2							
81	9N	8W	26		9	3	12	26	1				1	9				4		1				
82	9N	7W	25		11	7	4	18	5									7						
83	9N	10W	33		2		6	23	10	2			4	2			4							
84	9N	10W	36	3	6		4	23	3				5	3				4						
85	9N	9W	34	2		2	5	40	18					19	287		9							
86	9N	9W	35		7	3	1	255	141				4	2	36			2						
87	9N	8W	31		10	1	2	45	3					13	9							1		
88	9N	8W	32		2	4	6	46	4					11	6							1		
89	9N	8W	33		4	7	4	57	1					4	2			2						2
90	9N	8W	35				8	9	3					2										
91	9N	8W	36		2	3	19	19	3					2	5			2		2				
92	8N	11W	1				7	8	5												1			1
93	8N	10W	6		2		8	19	12					4			3							1
94	8N	9W	4	4	6		12	120	86					84	17		6				2			2
95	8N	9W	3		2	2	7	48	14					145	22		3							
96	8N	9W	2		6	4	21	242	5					4	32		2	4				2		2
97	8N	12W	11	2	14	4	8	61	25	5							7	4						10
98	8N	11W	9		3		24	33	19	3											2			10
99	8N	11W	11		2	6	5	24	27	3			1											12
100	8N	11W	12		2		6	71	18	1						1	3			1	1			4
101	8N	10W	7		3	2	26	43	22															2
103	8N	10W	9		6	3	23	35	12					1	1	1								3
104	8N	10W	11					18	2				1	2		1								
105	8N	10W	12					14	5				1				5				2			
106	8N	12W	13		4		8	17	14	1														1
107	8N	11W	16		2		4	16	3	3				1		1								3
108	8N	11W	15		2		2	61	21	5				3		1	2		1					4
109	8N	11W	13		3	3	1	277	30	3						1	2			2				2
110	8N	10W	18	2		1	15	51	59				2			5	2			4	1			
111	8N	10W	17	2	3	2	6	50	39							1	1							9
112	8N	10W	16		4	1	9	15	22		1													2
113	8N	10W	13		2			27	9					11										
114	8N	11W	20		1	1	10	29	14	3							5							3
Totals				15	86	77	93	105	99	25	10	2	56	65	34	9	23	34	10	12	9	7	5	47

Garbage was recorded in every section, with concentrations in 47 sections (45%) large enough to be considered dumps. The bulk of garbage in those sections was not of recent origin. The exception was in sections easily accessible to urban areas, notably the southwestern corner of the base near Lancaster, the town of Boron, and along public roads.

Spent shell casings were widespread and numerous. Shells were recorded on 99 sections (94%). Shooting targets were found in 25 sections (24%).

Fences and utility lines were recorded in 23 (22%) and 34 (32%) of all sections, respectively.

All other disturbance types were recorded on less than 15 percent of sections.

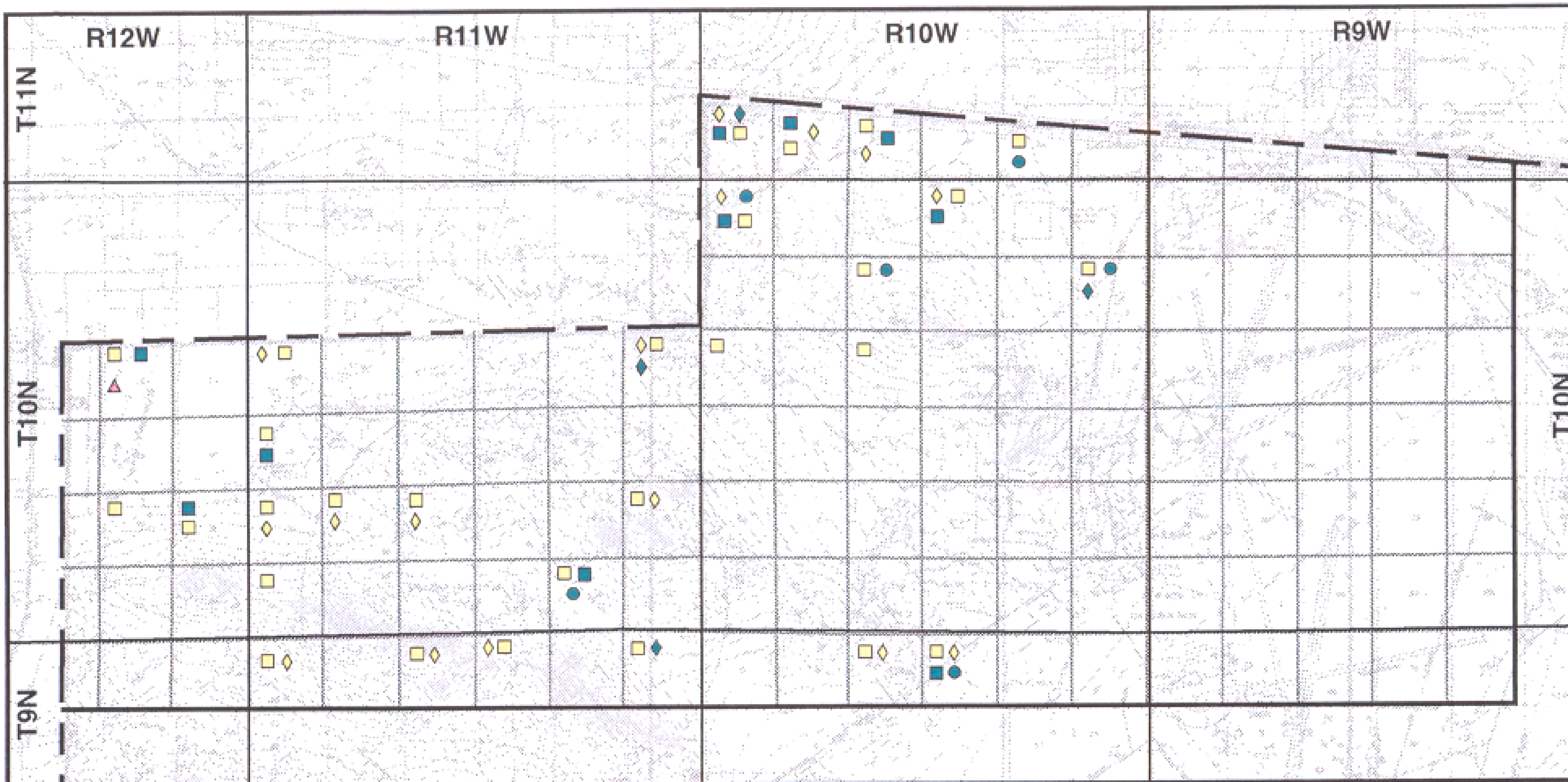
Other Special-status Species. Several sensitive species were observed or detected by sign during desert tortoise surveys at Edwards AFB. Table 5 lists these species along with their federal and/or state status and Figures 5-8 show their approximate locations in the study area. Our field methods were not suitable for detection of some taxa (e.g. bats), and this list of species is not intended to provide an exhaustive list of sensitive species on the site.

Table 5

Sensitive Species Observed or Detected by Sign in the Study Area

Species	Status
Northern harrier (*Circus cyaneus*)	Federal: None State: CSC
Prairie falcon (*Falco mexicanus*)	Federal: None State: CSC
Burrowing owl (*Athene cunicularia*)	Federal: None State: CSC
LeConte's thrasher (*Toxostoma lecontei*)	Federal: None State: CSC
Loggerhead shrike (*Lanius ludovicianus*)	Federal: FSC (C2) State: CSC
Desert kit fox (*Vulpes macrotis*)	Federal: BLM Sensitive State: None
American badger (*Taxidea taxus*)	Federal: None State: CSC

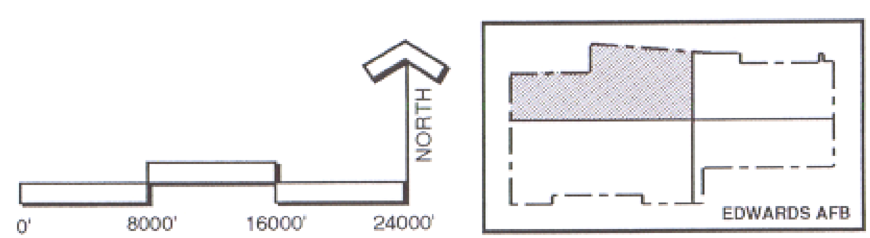
CSC=CDFG Species of Special Concern
FSC=Federal species of concern; formerly category 2 candidate species



LEGEND

- Base Boundary
- Mojave spineflower *(Chorizanthe spinosa)*
- Desert kit fox *(Vulpes macrotis)*
- American badger *(Taxidea taxus)*
- Short-eared owl *(Asio flammeus)*
- Burrowing owl *(Athene cunicularia)*
- Le Conte's thrasher *(Toxostoma lecontei)*
- Loggerhead shrike *(Lanius ludovicianus)*

FIGURE 5
INCIDENTAL SENSITIVE SPECIES DETECTIONS BY SECTION



E055_001.MRW 8/21/95

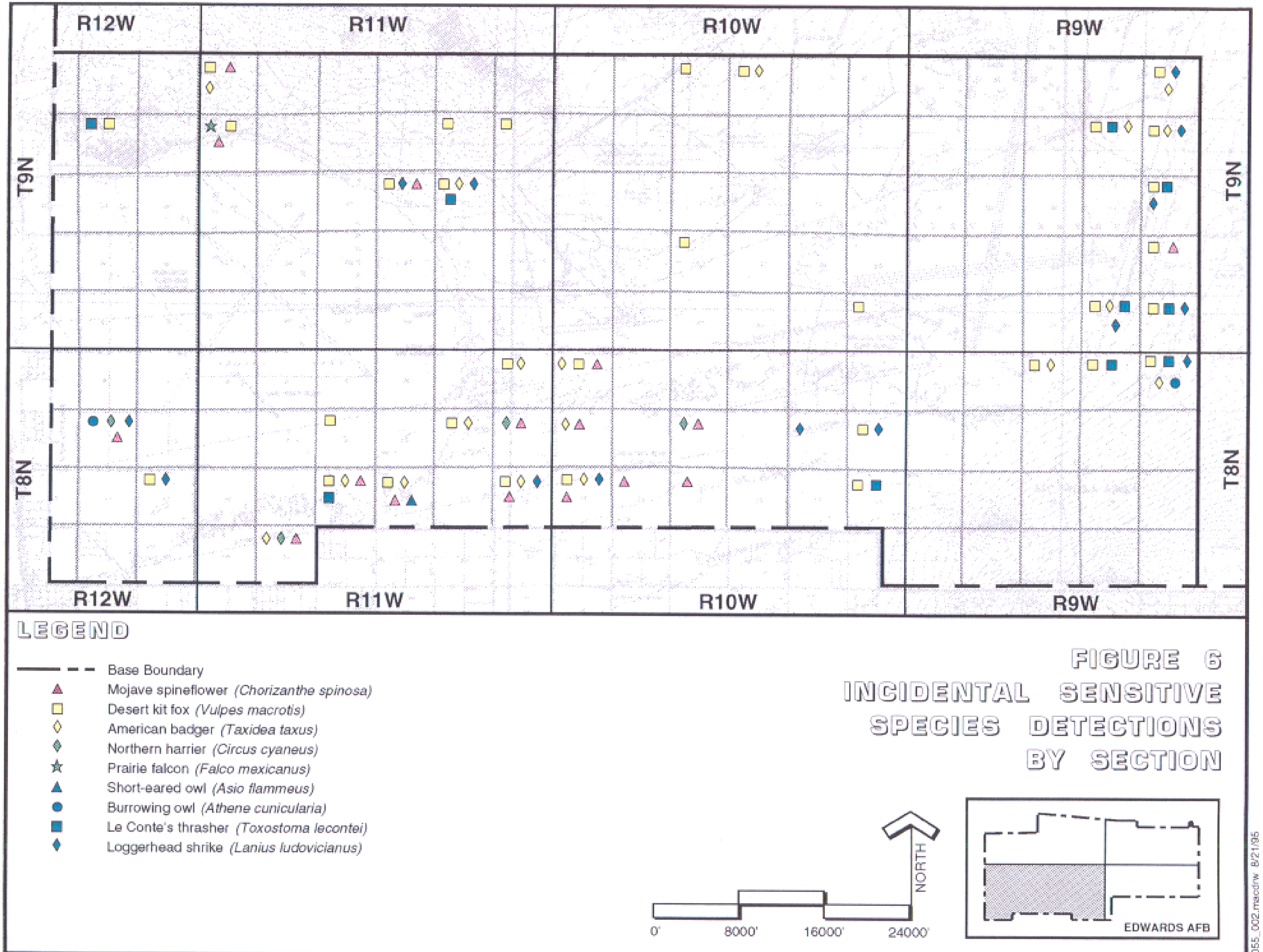


FIGURE 6
INCIDENTAL SENSITIVE SPECIES DETECTIONS BY SECTION

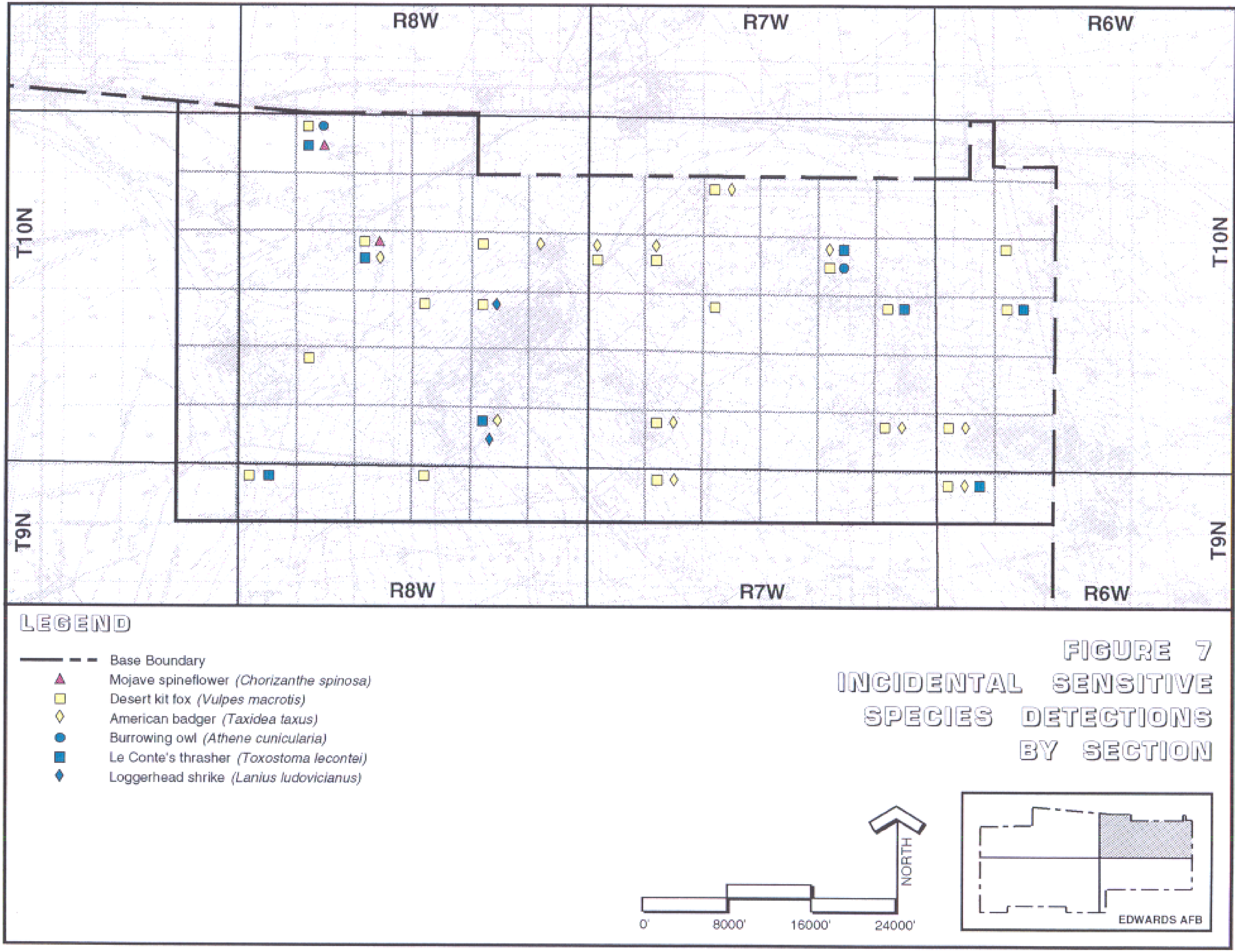


FIGURE 7
INCIDENTAL SENSITIVE SPECIES DETECTIONS BY SECTION

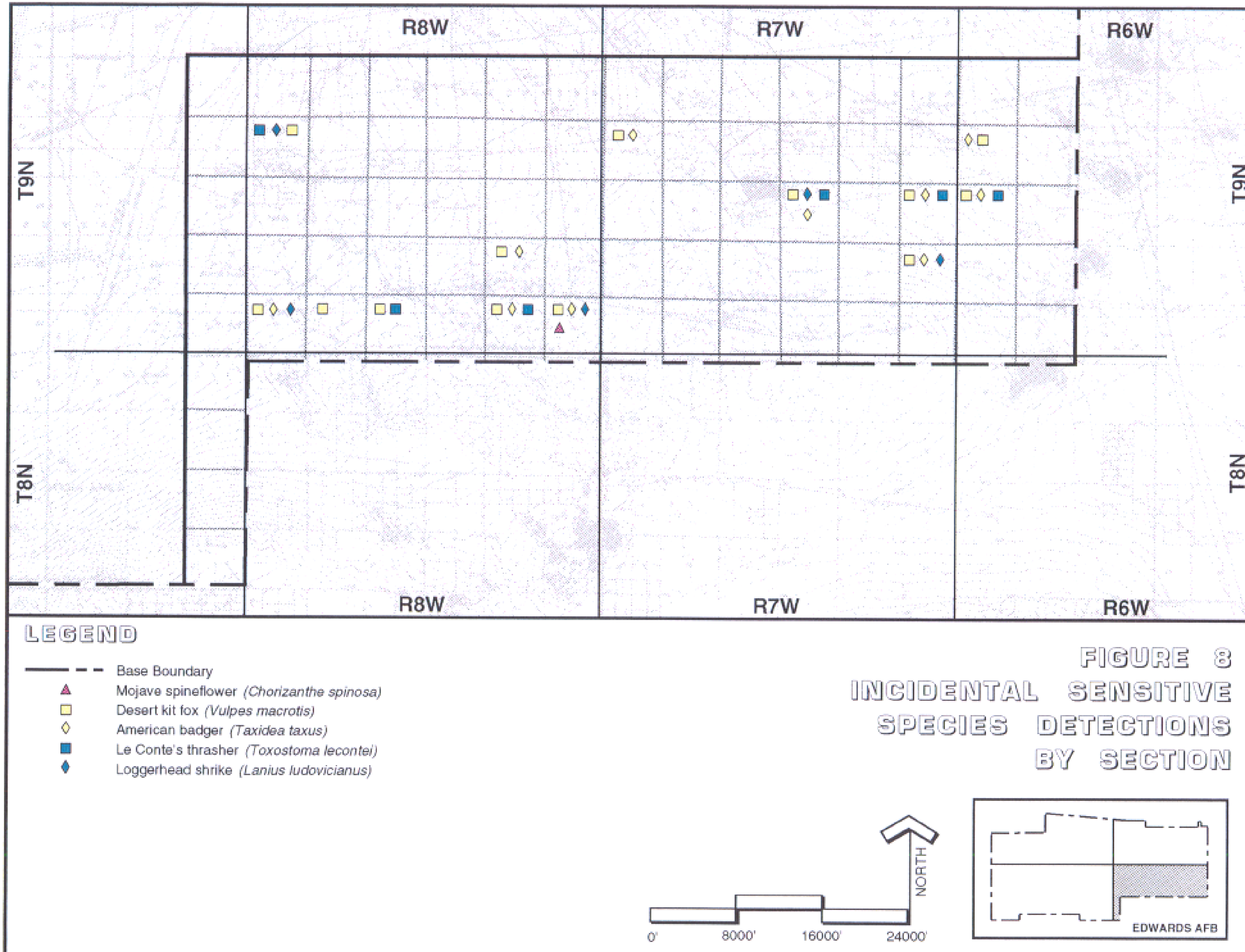


FIGURE 8
INCIDENTAL SENSITIVE SPECIES DETECTIONS BY SECTION

E055_003.macdrw 8/21/95

Two special-status mammal species were detected. Evidence of desert kit fox was detected in all habitat types throughout the study area. American badger sign was detected on 55 of the sections surveyed, primarily where fine-grained soils were prevalent.

Five special-status bird species were observed. LeConte's thrashers were observed on 34 sections, and several family groups were observed. Loggerhead shrikes were observed in 26 sections, either individually or in small family groups. Burrowing owls were observed or detected by sign in 10 sections. Northern harriers were observed on four sections. Prairie falcons were observed in one section.

DISCUSSION

The relative density strip transect methodology is designed to provide an estimate of tortoise density based solely on the presence of tortoise sign. This method was chosen because of its suitability for estimating relative tortoise densities over large areas (Berry and Nicholson 1979, 1984). The technique, therefore, only provides an approximation of relative density, and results can not be interpreted as absolute density. Since this study does not directly address specific surface disturbances, 100 percent coverage surveys were not necessary.

Several sources of error are inherent in any relative density index, and in this case, could involve observer bias, errors resulting from small sample size, and reliability of the relationship between sign and density. All three observers are experienced tortoise surveyors and had similar results at calibration plots. This methodology samples a very small proportion of each section (individual transects sample only 0.9% of a square mile, for a total of 2.8%). Therefore, sign counts may vary within a given section, especially if sign is patchily distributed. The methodology is not well suited for use in low density areas (Berry, personal communication). Positive correlation between tortoise density and sign is critical to the accuracy of the relative density index. There are several factors which could affect this relationship. There have been dramatic declines in tortoise populations in the northwestern Mojave in recent years (Berry, Goodlet, personal communication). This may affect the relationship between sign, which can persist for several years, and actual density. In addition, juvenile and hatchling tortoise sign is difficult to detect, and this portion of the population may be underestimated (Berry, personal communication).

The proportion of the tortoise population made up by sub-adults and juveniles (<140 mm MCL) was far greater at the Kramer Hills plot (54%) than at any other plot. For this reason, this plot was removed from regression analysis. Sign counts at the Fremont Peak plot may have been inflated by sign left by recently dead tortoise and by the presence of a tortoise near the center point. Results of calibration surveys using the remaining trend plots were similar to those which have been conducted in previous surveys at Edwards AFB, although the slope of the regression line was lower than in these studies (Mitchell et al. 1993; CSC 1991). The coefficient of determination (r2) for the three surveyors was 0.76, 0.75, and 0.73. These results are similar to those of other researchers at calibration plots (Karl 1981, r2=0.8; Berry et al. 1983, r2=0.76; Berry & Nicholson 1984, r2=0.79).

When combined with results of previous desert tortoise surveys utilizing the same techniques (Mitchell et al. 1993; CSC 1991), trends of tortoise distribution across Edwards AFB become apparent. Results indicate that desert tortoises are essentially absent from the southwest portion of the base. Concentrations of relatively high tortoise densities occur along the south edge of the base between Complex One Charlie and Red Buttes, around the north side of Leuhman Ridge and the Kramer Hills, and in small pockets in the Rosamond and Bissell hills.

REFERENCES

Berry, K.H. In preparation. Trends in California populations of desert tortoise: 1979-1993. U.S. Bureau of Land Management. Draft Manuscript.

Berry, K.H. 1986a. Desert Tortoise (*Gopherus agassizii*) Research in California, 1976-1985. Herpetologica 42(1):62-67.

Berry, K.H. 1986b. Desert Tortoise (*Gopherus agassizii*) Relocation: Implications of Social Behavior and Movements. Herpetologica 42(1):113-125.

Berry, K.H., and A.P. Woodman. 1984. Methods used in analyzing mortality data for most tortoise populations in California, Nevada, Arizona and Utah. Appendix VII in K.H. Berry (ed.), The Status of the Desert Tortoise (*Gopherus agassizii*) in the United States. Report. from the Desert Tortoise Council to the U.S. Fish and Wildlife Service, Sacramento, California. Order No. 11310-0083-81.

Berry, K. H., A. P. Woodman, L. L. Nicholson and B. L. Burge. 1983. The distribution and abundance of the desert tortoise on the Chocolate Mountains aerial gunnery range. In: K. Hashagen (ed.), Proceedings of the 1983 Desert Tortoise Council Symposium.

Berry, K.H., and L.L. Nicholson. 1984. The distribution and density of desert tortoise populations in California in the 1970's. Chapter 2 in K.H. Berry (ed.), The Status of the Desert Tortoise (*Gopherus agassizii*) in the United States. Report from the Desert Tortoise Council to the U.S. Fish and Wildlife Service, Sacramento, California. Order No. 11310-0083-81.

Berry, K.H. and F.B. Turner. 1986. Spring Activities and Habits of Juvenile Desert Tortoises, *Gopherus agassizii*, in California. Copeia 1986:1010-1012.

Computer Sciences Corporation. 1991. Estimates of Desert Tortoise Population Density on the 18-square Mile Complex One Charlie Area, Edwards Air Force Base, California. Contract No. F04611-87-C-0039.

Goodlet, G.O. 1990. Protocols for Conducting Desert Tortoise Surveys on the Edwards Air Force Base. Unpublished Internal document. Enviroplus Consulting. Ridgecrest, California.

Goodlet, G.O. 1991. Relative Density Transects. Unpublished Internal Training Document. Enviroplus Consulting. Ridgecrest, California.

Goodlet, G.O. 1992. Death Valley Proposal: Technical Approach. Unpublished Document. Enviroplus Consulting. Ridgecrest, California.

Karl, A. 1981. The distribution and densities of the desert tortoise, Gopherus agasizii, in Lincoln and Nye Counties, Nevada. In: K. Hashagen (ed.), Proceedings of the 1981 Desert Tortoise Council Symposium.

Mitchell, D.R. K.B Buescher, J.R Eckert, D.M. Laabs, M.L. Allaback, S.J. Montgomery, & R.C. Arnold. 1993. Biological Resources Environmental Planning Technical Report. Prepared in support of the Programmatic Environmental Assessment for Basewide Implementation of the Installation Restoration Program (IRP) at Edwards Air Force Base, California.

Mitchell, D.R. D.M. Laabs, M.L. Allaback, & R.C. Arnold. 1992. Potential Impacts of Installation Restoration Program Activities on Desert Tortoise (*Gopherus agassizii*), With Notes on Other Sensitive Species, Operable Unit No. 4, Edwards Air Force Base, California.

Weinstein, M.N. and K.H. Berry. 1988. Attempts to Validate a Habitat Model for the Desert Tortoise. Bureau of Land Management. Contract No. CA-950-CT7-003.

Personal Communications

Berry, K.H. Bureau of Land Management. Riverside, California.

Bransfield, R. U.S. Fish and Wildlife Service. Ventura, California.

Goodlet, G.C. Enviroplus Consulting. Ridgecrest, California.

Goodlet, G.O. Enviroplus Consulting. Ridgecrest, California.

ACKNOWLEDGMENTS

This work was performed by Tetra Tech Inc., and its subcontractors and consultants under contract to GRW Engineers, Inc. and the U. S. Army Corps of Engineers, Sacramento District, for the Air Force Flight Test Center, Environmental Management Office, Edwards Air Force Base, California, Contract No. DCA05-C-91-0130. Field surveyors and assistants included David Laabs, Mark Allaback, Ed LaRue, Kathy Buescher, Brenda Ellis, and Jody Sawasaki. Ed Hickey of GRW Engineers provided GPS support. The authors wish to thank the many people who contributed to this effort. Special thanks to Mark Hagan, Base Biologist, the project proponent and other members of the Environmental Management Office including Wanda Deal, Veronique Anderson, Captain Tom Rademacher, Don Cowan and Virginia Mathys for immeasurable technical, logistical, and other support. Thanks also to the Tetra Tech production staff for substantial technical writing, editing, peer review, word processing, graphics preparation and data analysis. The production team for this report included: Dovey Dee, Cindi Dreyer, Grace Fermier, Steve Hoerber, Mary Jones, Becky Oldham, Jacquie Smith, and Ben Weink.